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CRITICAL ANALYSIS OF THE METHODOLOGY ADOPTED BY CERTAIN CAMEROONIAN STUDIES FOR THE EVALUATION OF THE WIND SPEED: CASE OF THE ECONOMICAL CITY OF DOUALA

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ABSTRACT

In the design of different types of building and storms, one takes often into account the action of the wind speeds and the requirement of the reference speed. The estimation of the reference is made by a statistical treatment of wind speeds recorded at meteorological stations. Some countries, such as France, have divided their territory into regions and proposed the reference velocity values to be adopted for each region. In Cameroon, in the absence of country-specific values, design offices adopt French values according to the topographical similarities between a French region and the Cameroon region where the Civil Engineering project will be built. To verify the validity of the process, we calculated the wind reference speed in the city of Douala on the basis of surveys carried out over a period of 40 years (1971-2010) by applying the regulatory requirements. The value obtained is lower than that of the corresponding French region adopted by the consulting firms. It is also weaker than those adopted by some countries such as Algeria, South Africa or Belgium. This can be explained by the fact that Douala and Cameroon are in the so-called equatorial calm zone which is characterized by low-intensity winds.

Key words: Designing, Wind speeds, Reference speed, Statistical analysis, French and Cameroon region

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1. INTRODUCTION

The wind has many influences in the design of building of storms. This action is evaluated on the basis of the specific regulations to each country. In Africa, only Algeria and South Africa have developed their own regulations [1,2]. Francophone African countries use almost all French regulations. The Standard "Neige et Vent 65"(NV65) is the first French regulation [3]. It was adopted in 1965. After several revisions it was replaced by the standard "Eurocode1" common to all countries of the European Union [4]. Whatever the norm, the estimation of the wind action is always based on the calculation of the reference speed of the wind blowing in the region where it is planned to implant civil infrastructures (buildings, bridges , Pylons, etc.). The random nature of this action necessarily leads to a probabilistic approach. Thus the reference values are calculated on the basis of a statistical treatment of wind speed readings carried out in meteorological stations over a sufficiently long period. Some countries, such as France, have adopted several benchmarks depending on the region. The following Table 1 presents the so-called standard reference speeds proposed by the modified version NV65 of the year 1999, while Table 2 presents those proposed by the French National Application Document (DAN) of Eurocode 1. The difference in values between the two tables reflects a difference in approach between the two regulations as will be explained in the next paragraph.

Table 1 Normal wind reference velocity V_n in France by modified NV65 of 1999[5].

Region	1	2	3	4	5
V_n (m/s)	28.6	31.3	35.0	38.3	44.2

Table 2 French wind reference velocity V_{ref} transferred by the French National Application Document of Eurocode 1 [4].

Region	1	2	3	4	5
V_{ref} (m/s)	24.0	26.0	28.0	30.0	34.0

South Africa [Table 3] and Algeria [Table 4] have also adopted several benchmarks.

Table 3 Wind reference velocity V_{ref} adopted by the South African regulation [6].

Region	1	2	3
V_{ref} (m/s)	28.0	32.0	36.0

Table 4 Values of wind reference speeds V_{ref} adopted by the Algerian RNVA 99 regulation [1].

Region	I	II	III
V_{ref} (m/s)	25.0	28.0	31.0

On the other hand, several countries of the European Union in their National Application Documents of Eurocode 1 have a single reference value throughout their territory [Table 5].

Table 5 Values of wind reference speeds V_{ref} adopted by certain countries of the European Union [4].

Countries	V_{ref} (m/s)
Belgium	26.2
Denmark	27.0
Finland	23.0
Luxembourg	26.0

At present, Cameroon does not yet have its own regulations. It is for this reason that the design offices of this country adopt the values of the French reference speeds according to the topographical similarities that can exist between the French and Cameroonian regions. To verify the validity of this approach, we have calculated the wind reference speed of the city of Douala by drawing on both the recommendations of the World Meteorological Organization (WMO) and the two standards Used in Cameroon, namely the French regulation NV65 and the Eurocode 1. This value, calculated based on 40-year speeds (1971-2010) will be compared with that adopted by the engineering firms in this city and in addition to the reference values of the other countries presented in Tables 1 to 5.

The rest of the paper will be organized as follows: section 2, regulatory requirements; section 3, calculation of the reference speed of the city of Douala; and finally a conclusion in section 4.

2. REGULATORY REQUIREMENTS

The top speed is the near instantaneous value of the wind speed. The mean reference velocity is the mean velocity calculated in a time interval of 10 minutes of the wind measured under conventional conditions [7]. Dealing with the reference speed, NV65 defines two [3]: the normal speed V_n(the top speed that is reached or exceeded only 3 days out of 1000)and extreme speed V_{ext} (the highest instantaneous velocity at which the construction can be subjected during its lifetime).

Eurocode 1 defines a single wind reference speed V_{ref} [4], as the average speed corresponding to an annual overshooting probability of 0.02 or an average return period of 50 years.

Note that the reference speed in the NV65 is based on the top speeds while in the Eurocode is based on the average speed. The sampling will not be the same for the two approaches: In the NV65, sampling will consist of a series of peak speeds, whereas in the Eurocode it will consist of a series of average speeds over 10 min. Strictly, the analysis should be carried out on the recording tapes.

In modern meteorological stations, an evaluation is carried out through [7]:

- The instantaneous wind speed and direction (calculated on 0.5s every 0.5);
- The average speed and direction of the wind (calculated over 10 minutes every minute);
- The Extrema Of the wind (direction and speed) over a period of 10mn refreshed every minute.

2.1. Sampling and duration of observation

To obtain the reference speeds of the wind according to the standards, a statistical treatment of the speeds recorded in the meteorological stations is necessary. It is necessary to construct a sample of data on the basis of the values of the speeds recorded over a given period.

Eurocode 1 advocates a return period of 50 years. As a general rule, confidence in a return period declines rapidly when its duration exceeds about twice that of the collection of data [7]. Thus, for a return period of 50 years, it would take at least 25 years of records. Several possibilities for the construction of sampling may be envisaged:

Based on the average or peak values are taken into account, which corresponds to one per minute, ie 13,140,000 values over 25 years.

Based on the average or the highest value of the recording data over a given period, which may be daily (9125 values), weekly (1300 values), monthly (300) or annual (25), is taken into account.

Each approach presents advantages and disadvantages that should be analysed.

The first approach would be ideal, but handling such a mass of information poses storage and processing problems. It also raises the problem of data independence. The worry in working with the weekly, monthly and annual values is that much of the information is necessarily lost. A weekly data is the representative of 10 080 speeds, a monthly data is the average representative of 43 200

speeds and an annual data represents on average 524 160. This mass of lost information cannot be recovered when estimating the reference speed.

A study by Janie Coulombe [8] shows that the correlation between the velocities Averages over 10 minutes and days can be lifted by making averages over three days. This option allows it to reduce the dependence between observations. The ideal sampling would therefore consist of daily average or maximum values over at least 25 years in order to have estimates consistent with WMO recommendations.

2.2. The Statistical Laws and Domain of Use

In order to obtain the reference wind speeds, we first built a functional relation between the large scale (characteristic of storms) and the small scale (observation of winds at ground level). In a second step, this function is applied to two general circulation models that automatically and objectively identify the most distinctive characterizations associated with perturbations in a temporal series of meteorological data.

From a schematic point of view, two types of laws can be distinguished: laws based on the theory of extreme values and others laws.

2.2.1. Laws based on the Theory of Extreme Values

For the study of a series of data consisting of peak or maximum mean speeds, the most widely used statistical model is the extreme value theory, which consists of the Generalized Extreme Values Laws (GEV) and the Generalized Pareto Laws (GPD). The latter are used to simulate extreme values in a distribution.

2.2.1.1. Generalized Extreme Values Laws

The study of extremes involves the analysis of the maximum of a given sample of size n. Let $X_1, X_2, \dots, X_n$be a sample of independent and identically distributed random variables and$M_n = \max\{X_1, \dots, X_n\}$, the highest value of the sample. As far as we are concerned, $X_1, X_2, \dots, X_n$ represent observations of average wind speed during n period (which may be day, week, month, or year). Analysis of the maxima of samples of size n is also called analysis of maxima per block (Figure 1 below). For the case of our study, a block corresponds to a month and $M_n$is the monthly maximum. We are then interested in the law of distribution of maximum M_n.

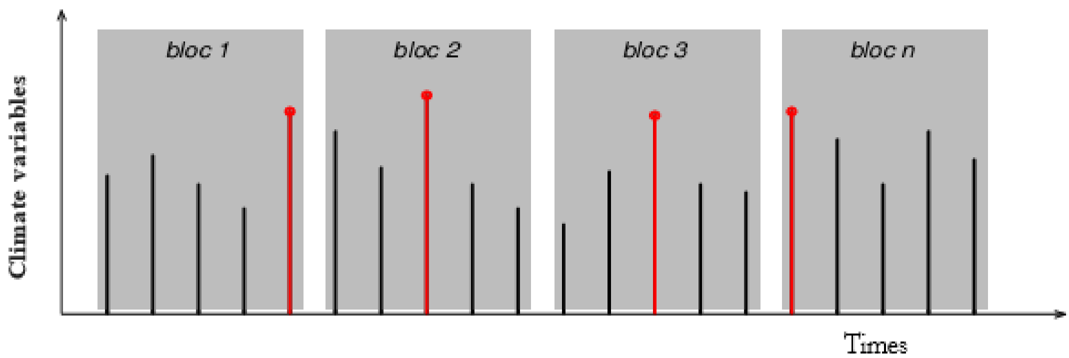


Figure 1 Diagram of the method of maxima per block. The maxima of the blocks follow a GEV law. [9]

The Fisher-Tippet theorem forms the basis of the modeling:

If there exist two real constants $a_n > 0 \; et \; b_n$ (weak convergence), such that: as $n \to \infty$,

$P\left\{\frac{M_n - b_n}{a_n} \leq X\right\} \to G(X)$ (weak convergence), G being a non-degenerate distribution function (ie not concentrated at one point).

The distribution law of the maximum limit G can be deduced by using the property of max-stability [10]. This is equivalent to find G only in the group of distributions for which the distribution function of the maximum of a finite sample of the independent random variables and identically distributed belongs to the same type of distribution as the distribution function of the random variables. Then G can belong only to one of the three following laws: Weibull, Gumbel or Fréchet. It is the same logic that leads the normal distribution in the central limit theorem (the average of the normally distributed observations follows a normal distribution).

Let $\xi \in \Re$ be a shape parameter called an index of extreme values, $\sigma > 0$ scale parameter, also called dispersion parameter and μ actual position parameter. Under these conditions, the function $G(X)$ is defined on $\{X \in \Re : 1 + \xi\left(\frac{X-\mu}{\sigma}\right) > 0\}$ by:

$$G(X) = \begin{cases} \exp\left\{-\left[1+\xi\left(\frac{X-\mu}{\sigma}\right)\right]^{-\frac{1}{\xi}}\right\} si\ \xi \neq 0 \\ \exp\left\{-exp\left[-\left(\frac{X-\mu}{\sigma}\right)\right]\right\} \text{si } \xi = 0 \end{cases} \quad (1)$$

The distribution of the maximum of a sample of sufficiently large size approaches asymptotically a GEV distribution. In a manner similar to the mean and standard deviation of the normal distribution, the GEV position parameter determines where the distribution concentrates and the scale parameter the wide of the distribution. If X is a random variable which follows the GEV distribution, then, the standardized variable$(X - \mu)/\sigma$ has a distribution that does not depend on μ, nor on σ but only on ξ. The behavior of the extremes is then controlled by the sign and the value of ξ according to the sign of the shape parameter. Therefore, three types of GEV are defined:

$\xi = 0$, Light-tailed laws (or Gumbel's distribution);

$\xi > 0$, Heavy-tailed laws (or Fréchet distribution);

$\xi < 0$, Bounded distribution (or Weibull distribution). (2)

2.2.1.2. Generalized Pareto Laws

To be able to exploit more data and not only the maxima of the blocks, several alternative approaches to the analysis of maxima have been developed. One approach is to consider the overrun of a high threshold (Figure 2 below). This method, based on the work of J. Pickands [11] and A.C. Davison [22], is more recent and is little more independent from the problems associated with the hypotheses of independence of observations. It will involve the choice of a threshold beyond which the model can be applied. It is sensitive to data disruptions.

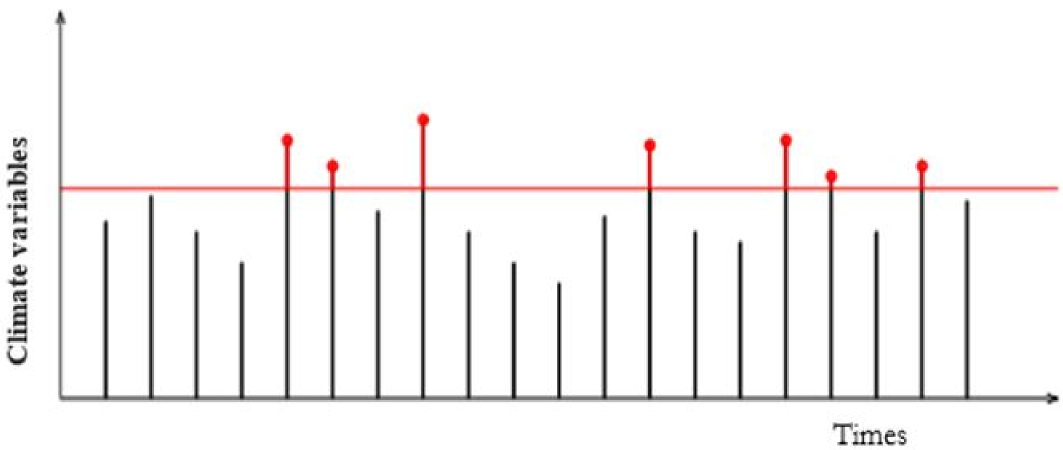


Figure 2 Diagram of the method of exceeding a threshold. Excessive thresholds follow the GPD law. [9]

Let $X_1, X_2, \ldots$ be a sample of independent and identically distributed random variables of law G and $M_n = \max\{X_1, X_2, \ldots, X_n\}$. Suppose that G satisfies the limit theorem GEV, that is, for a very large n, we can write $P(M_n < X) \approx G(X)$, where G(X) belongs to the family of GEV distributions with position, scale and shape parameters noted μ, σ, ξ. Pickands [11] showed that for a threshold u sufficiently high, that is to say when $u \to \infty$, G can be approached by H, as follows:

$$G(y) \approx H(y) = \begin{cases} 1-\left(1+\frac{\xi y}{\sigma_u}\right)^{-\frac{1}{\xi}}, \xi \neq 0 \\ 1-\exp\left(-\frac{y}{\sigma_u}\right), \xi = 0 \end{cases} \quad (3)$$

H defined on $\left\{y: y > 0, \left(1+\frac{\xi y}{\sigma_u}\right) > 0\right\}$, with $y = X - u$ and $X > u$, $\sigma_u = \sigma + \xi(u - \mu)$.

The shape parameter ξ is the same as the one of the GEV laws in the preceding subsection. This family of laws constitutes the generalized Pareto laws (GPD), with σ_u as the scale parameter.

The above result implies that if the maxima of the blocks have a limit distribution G, then the threshold overruns have approximately a distribution of the corresponding generalized Pareto family. In addition, the parameters of the GPD distribution are only determined by those of the associated GEV distribution. In particular, the scale parameter, which governs the distribution width, is defined by the following relation:

$$\sigma_u = \sigma + \xi(u - \mu) \quad (4)$$

Therefore, we have depending of the form's parameter:

$\xi = 0$, Unbounded light-tailed laws (or exponential distribution);

$\xi < 0$, Heavy-tailed laws (or Pareto distribution);

$\xi > 0$, Distribution bounded above $u - \frac{\sigma}{\xi}$ (or Beta distribution). (5)

2.2.2. The other Laws

2.2.2.1. Law of Weibull

There are two types of Weibull laws, the first leant on three (03) parameters is part of the laws of the extreme value theory as we present in the preceding subsection and the second leant on two (02) parameters which is the subject of this paragraph. The Weibull law describes the time intervals between phenomena that can occur continuously and independently through a variable frequency. The Weibull function allows us to characterize the frequency distribution of wind velocities over a given period. It is defined by the following equation:

$$f(U) = \frac{k}{c}\left(\frac{U}{c}\right)^{k-1} \exp(-\left(\frac{U}{c}\right)^{k}, \quad (6)$$

where

- f(U)is the Weibull probability density function: F(V)is therefore the probability of observing a wind speed V, in m/s ;
- c, in m/s, is the scale factor of the Weibull law. It is connected to the average wind speed by the form factor k;
- k is the form factor of the Weibull law, describing the distribution of wind velocity. The associated cumulative distribution function is therefore given by:

$$F(V) = 1 - \exp[-\left(\frac{V}{c}\right)^{k}] \quad (7)$$

The relation between the scale factor of the Weibull law and the average wind speed is given by the following formula:

$$c = \frac{V_n}{\Gamma\left(1+\frac{1}{k}\right)} \tag{8}$$

with:

- Γ, the Gamma function;
- V_n, in m/s, the average wind speed;
- k, the form factor of the Weibull law.

The estimation of the parameters k and c makes possible the characterization of the statistical distribution of the wind speeds over a given period.

2.2.2.2. The Law of Gumbel

Such as for the Weibull law, we also have two types of Gumbel laws, the first of three (03) parameters contained in the laws of the extreme value theory view in the preceding subsection and the second of two (02) parameters which is the subject of this paragraph. Gumbel's analysis allows a regression curve to be adjusted according to the occurrence frequency of events in the past and to predict the likelihood of occurrence of a larger event with a longer return period than available data. This adjustment is based on a double exponential law according to a method described by Gumbel [12]. For a given series of wind measures, the maximum value (gust and average wind speed over 10 minutes) measured during each year or month is retained. These maximum values are then classified by group for which the frequency of occurrence is calculated as a function of the double exponential law of Gumbel $u = -\ln(-\ln(1-1/T))$ and T is the return period expressed in years or months. A linear regression line can then be adjusted as a function of different values of u obtained and the annual or monthly maximum values measured. [13].

2.2.2.3. Log - Normal Laws

These laws are used in the same way as normal laws, but there require the measures or observations to be the result of a multiplicative effect of a very large number of other variables, independent of each other and individually negligible. Besides applications in biology in the multiplicative effect of a dose of a substance, we also have applications in insurance where the Log-Normal law can represent the distribution of the costs of claims. The Log-Normal law is more generally used, when the distribution of the observations is very asymmetrical. A random variable X follows a log-normal law when its logarithm follows a normal distribution that means $Y = L_n X$ follows a law N (α; β) with α and β the parameters of the normal distribution.

$$g(X) = \frac{1}{X} \times \frac{1}{\beta\sqrt{2\pi}} \times e^{-\frac{1}{2}((L_n(X)-\alpha)/\beta)^2} \tag{9}$$

α and βare the parameters: $\alpha = \mu_y$ (expectation of $L_n X$) and $\beta = \sigma_y$ (standard deviation of $L_n X$).

2.3. Criteria for choosing the most Appropriate Law for a given Situation

2.3.1. Visual Examination of the Adjustment

To judge the quality of the fit of a given distribution to a theoretical model, we can use a graphical tool, as the Quantile-Quantile or Q-Q plot diagram. Here is the principle: from the data observed, a number of quantiles are calculated. If the statistical series adjusts well to the theoretical distribution, we should have the observed quantiles equal to the quantiles of the theoretical distribution. Graphically, we place on a cloud of points the quantiles of the two distributions (On the abscissa, the theoretical quantiles and on the ordinate, the quantiles observed). The adjustment of the distribution given to the theoretical model will be relevant if the points are positioned along the first bisector.

2.3.2. The Kolmogorov-Smirnov Test

The Kolmogorov-Smirnov test is used to determine whether a statistical series follows a given law known by its continuous distribution function, or simply if two statistical series follow the same law. It consists on the comparison of the distribution functions of the two statistical series. If $F_0(X)$ is the theoretical distribution (first series) and $F(X)$ is the experimental distribution (second series), the assumptions of the test are defined such that we have $H_0: F(X) = F_0(X)\ \forall\ X$ and $H_1: F(X) \neq F_0(X)$. It comes out that, we need to measure for a continuous random variable the greatest distance between the theoretical distribution $F_0(X)$ and the experimental distribution $F(X)$. The empirical or observed distribution is calculated in the theory of Kolmogorov-Smirnov by the classical relation:

$$F\left(X_{[r]}\right) = \frac{r}{n} \tag{10}$$

Then, the distance d is defined as follows:

$$\begin{cases} d^+ = \mathrm{Max}\left\{\frac{r}{n} - F_0\left(X_{[r]}\right)\right\}, \forall r = 1,2, \ldots n \\ d^- = \mathrm{Max}\left\{F_0\left(X_{[r]}\right) - \frac{r-1}{n}\right\}, \forall r = 1,2, \ldots n \\ d = \mathrm{Max}\{d^+; d^-\} \end{cases} \tag{11}$$

There are several books in which we can found the tabulation of d.

Let D be the random variable associated to d.

Under the hypothesis H_0, d tends to 0. The distribution of D is the subject of the Kolmogorov tables, which take into account the sample size and the accepted risk threshold: it is then sufficient to compare D to the appropriate value of D in the table.

The non-rejection of H_0 means that the two distributions follow the same law, statistically speaking.

2.3.3. Test of Anderson–Darling

The Anderson-Darling test is another variant of the Kolmogorov-Smirnov test, with the difference that it gives more importance to the tails of distribution. The principle is the same as the one of Kolmogorov-Smirnov. The test statistic A^2 is as follows:

$$A^2 = \int_{-\infty}^{+\infty} [F(X) - F_0(X)]^2 w(X) dF(X), \tag{12}$$

where $w(X)$ is a weighting function.

The Anderson-Darling standard case corresponds to the following weighting function:

$$w(X) = 1/(F_0(X)[1 - F_0(X)], \tag{13}$$

Which allows to give more influence to low and high frequencies. This leads to the statistic noted A^2.

By changing the weighting function into:

$$w(X) = \frac{1}{1-F_0(X)}, \tag{14}$$

we will get a behaviour-sensitive test for rare frequencies. This test procedure can be especially useful, as generally in the case of hydrology, when we are interested in extreme values. Like the kolmogorov-Sminorv test, the non-rejection of H_0 means that the two distributions follow the same law, statistically speaking.

2.4. Procedure for Determining the most Appropriate Law

The appropriate law for the calculation of reference speeds cannot be defined. It is a function of the data series. The laws differ from country to country. In Switzerland, for example, the Gumbel law is used, whereas in the United States of America it is more the Log-normal distribution of Weggel [14] which is used. The statistical approach to finding the statistical law that suits our data sample is frequency analysis.

Frequency analysis is a statistical method of prediction consisting in studying the past events, characteristic of a given process, in order to define the probabilities of future occurrence. This method of prediction relies on the definition and implementation of a frequency model, which is a parametric equation describing the statistical behaviour of a process. These models describe the frequency of occurrence of a windy phenomenon of given value. It consists of several stages, schematized simply according to the diagram below:

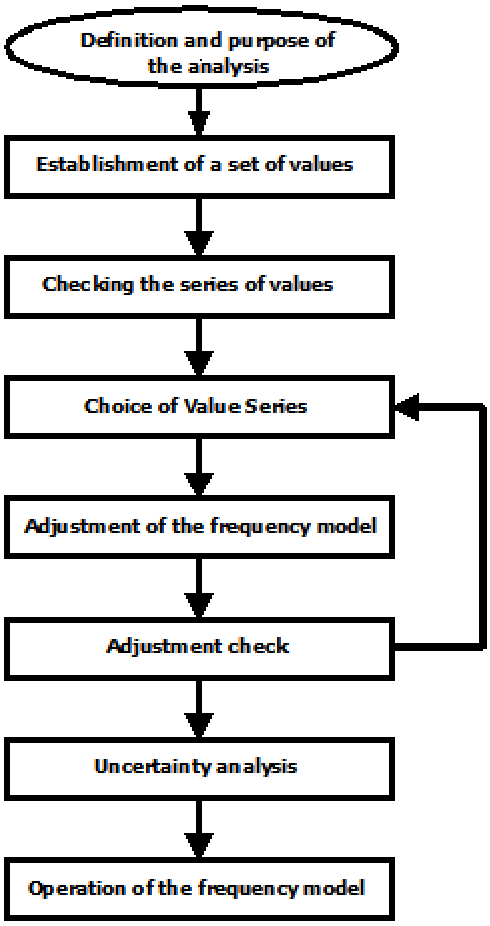


Figure 3 Flow chart of a frequency analysis. [15]

The use of the flow chart is simple, we first define the purpose of the analysis which is here to determine the reference wind speeds. Then we have our data set. The question is, what kind of data is needed? In our case we need the average speed over 10 minutes.

The construction of a series of values, constituting a sample in the statistical sense of the term, is a long and delicate process because errors can be committed. Errors may occur in one or other of the four phases of the conventional operation, namely: measurement, transmission of information, storage of information, treatment of information (pre-treatment and analysis). It is therefore essential, before using data sets, to check their quality and their representativeness by using various techniques in

general of statistical or graphical type. It also involves the detection of aberrant data, so as not to confuse them with extreme values.

The validity of the results of a frequency analysis depends on the choice of the frequential model and more particularly on its type. Various tracks can help to facilitate this choice, but unfortunately there is no universal and infallible method. For the choice of the frequency model, one can rely on the theoretical considerations that list the various laws used in the field. It can also be based on experience and custom (the law generally used to calculate wind speeds in a given region) or by tests of adequacy.

Adjustment consists of finding the parameters of a mathematical function in order to match an experimental curve. The results may be different according to the methods used for the same phenomenon.

The control consists in checking whether a statistical distribution observed on a sample conforms or not to a given theoretical model, in other words, if a theoretical probability law can better represent the distribution of the frequencies of the values taken by a character C, in a sample E of elements randomly taken from a set P (adjustment of these experimental data to the theoretical law). The adjustment tests to a theoretical law are very varied and the use of one or other requires a lot of attention and verification of the conditions of application.

2.5. Missing or Incorrect Data

Missing or erroneous data at a station can be estimated from values recording in neighbouring stations subject to the same climatic conditions and within the same geographic area and from statistical functions. The quality of the estimate is better when it concerns only one or a few observations over a long continuous period of missing or erroneous observations. Thus, the longer is the period to be filled, the lower the degree of confidence that can be given to the estimates. Kotsiantis [16] presents several methods to complement the climatic series:

- Ignorance of Unknown Values: This method is the simplest, just ignore cases that have at least one unknown characteristic value.
- Most common characteristic value: The value that most often occurs is selected to complete all unknown values.
- Average of substitution: The missing values are supplemented by the average of the available values.
- Regression or classification: A regression or classification model is developed on the basis of completed data, and then applied to the missing data.
- Hot Deck Imputation: The most probable case for a certain variable is identified and is used to replace the missing values.
- Processing Missing Values as Special Values: The unknown value is treated as a new value for functions that contain missing values.

It is also possible to extend the available data of a region by increasing the size of the sample in order to have a representative set of data [17].

An interpolation aimed at filling missing data from one station to another is possible but requires a thorough knowledge of the modeling of the wind regime between the stations, since many factors such as topography and local features influence the regime of a region. It is important to note that their processing is very complex, because the more variable is the regime, it is difficult to find a valid interpolation model. Such an approach is possible in regions of homogeneous climatology. It is still difficult to apply because extreme wind events can be generated by storms and a sampling of recordings of short duration generates errors in the estimation of wind speeds.

3. CALCULATION OF REFERENCE SPEED OF THE CITY OF DOUALA

3.1. Methodology

For the calculation of the reference speed in the city of Douala, we will assume that the series is identically distributed. Then, we will study the dependence between the data. In case where the data are dependent, the seasonal component in the series will be removed. We will estimate the parameters of the law and estimate the quantiles. At the end we will add the seasonal component to obtain the actual values of the reference speed.

3.2. Software used

For a graphical representation of our data series and to check that the series is seasonal or not, we will use the graphical tools of Microsoft Excel 2013 [18]. The histogram of the series will be done with the software Eviews9 [19] to have the basic characteristics of our series. We will use the software R to be able to work on the extreme values without any programming ourselves. The "evd: extreme value distributions" package of R software proposed by Alec Stephenson allowed us to estimate the quantiles. The R software will also allow us to do the Kolmogorov-Smirnov test and the graphics tests [20].

3.3. Calculation Steps

3.3.1. Presentation of Data

For our study we worked with the monthly maximum speeds of the city of Douala in Cameroon. The meteorological station of Douala is situated at 9 m altitude, latitude 4 ° N and longitude 9 ° 733'N. We have monthly wind speeds for a period of forty years from the Coastal Meteorology delegation. We will assume that our data are homogeneous and the data are shown in Table 6 below:

Table 6 Wind speed data for the city of Douala from 1971 to 2010 in m/s.

YEAR	JAN	FEB	MARCH	APRIL	MAY	JUNE	JUL	AUG	SEPT	OCT	NOV	DEC	Max
1971	8	13	13	14	12	10	7	8	9	9	8	7	14
1972	7	15	15	11	12	7	7	7	9	6	6	6	15
1973	7	15	12	14	10	11	9	28	10	10	7	9	28
1974	7	11	9	12	9	11	7	7	7	8	8	6	12
1975	7	15	12	14	10	11	9	9	10	9	7	9	15
1976	7	12	10	11	8	10	7	10	11	18	13	9	18
1977	9	10	15	27	27	26	10	10	11	11	11	13	27
1978	10	17	11	15	16	11	11	11	11	11	15	8	17
1979	10	17	12	12	18	11	12	10	10	11	13	8	18
1980	7	10	18	15	14	13	10	10	11	13	14	8	18
1981	10	9	12	13	14	15	10	9	12	15	10	9	15
1982	10	8	18	15	14	13	11	10	10	12	9	8	18
1983	6	11	21	15	16	12	9	8	8	13	10	12	21
1984	7	15	15	15	14	12	9	9	9	12	9	6	15
1985	5	6	7	6	6	6	5	5	6	4	6	5	7
1986	5	6	8	7	7	7	6	6	7	7	7	5	8
1987	6	6	6	7	7	6	6	6	7	6	7	5	7
1988	6	6	6	6	7	7	7	8	8	9	9	9	9

YEAR	JAN	FEB	MARCH	APRIL	MAY	JUNE	JUL	AUG	SEPT	OCT	NOV	DEC	Max
1989	8	10	10	11	8	9	8	9	10	10	10	9	11
1991	8	9	9	9	9	10	9	9	10	10	9	7	10
1992	7	5	6	6	5	5	5	6	6	5	4	4	7
1993	9	13	18	17	18	10	10	10	11	13	15	14	18
1994	8	8	11	11	10	10	9	7	8	8	7	8	11
2001	6	7	8	12	10	7	6	6	6	6	6	12	12
2002	5	6	28	20	13	6	6	8	9	10	8	8	28
2003	6	20	6	13	6	7	7	7	6	7	7	5	20
2004	7	7	6	12	6	12	8	6	7	7	11	9	12
2005	9	12	8	7	6	6	6	6	6	6	6	5	12
2006	7	8	8	7	9	6	6	6	7	6	5	5	9
2007	5	5	10	7	7	7	21	24	24	10	10	10	24
2008	5	6	9	6	10	6	6	6	7	6	6	8	10
2009	7	8	8	6	7	5	6	5	6	6	5	5	8
2010	4	4	2	2	4	3	4	6	5	4	5	4	6
Max	15	20	28	30	20	16	21	24	24	15	16	14	30

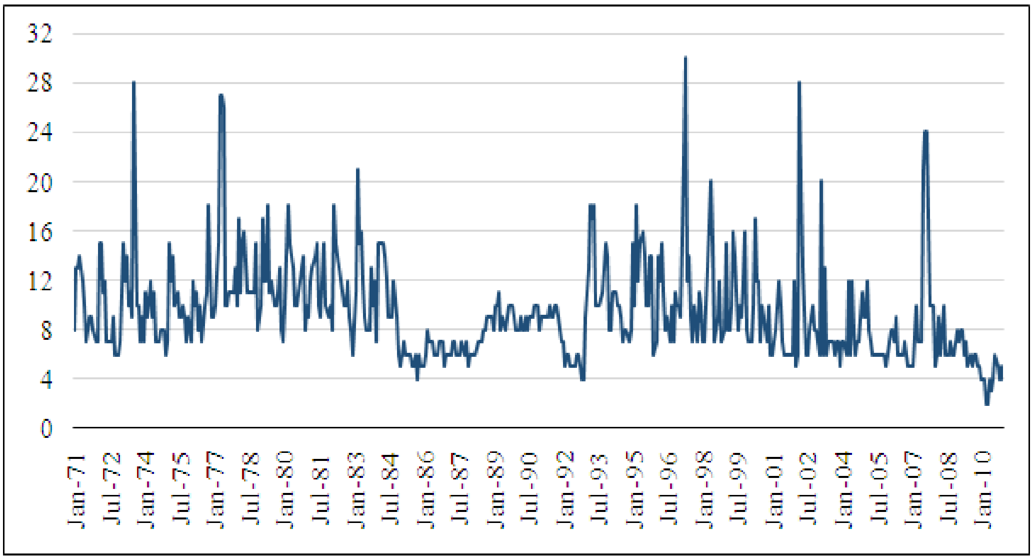


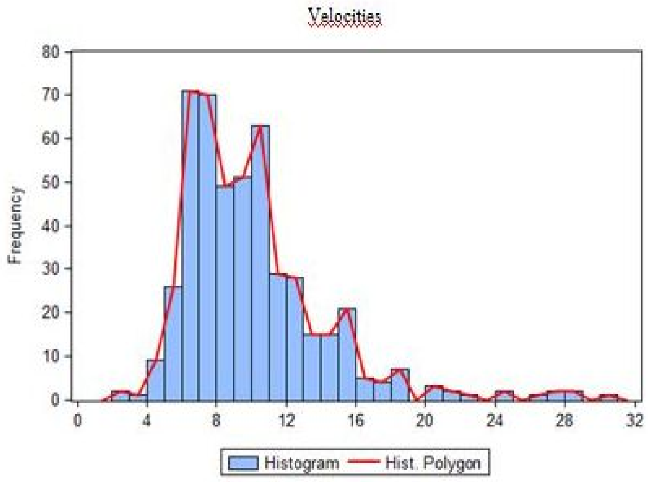
Figure 4 Representation of the monthly wind speed series of the city of Douala from 1971 to 2010 (in m / s) (MS Excel 2013).

Observing the series of monthly wind speeds presented in Figure 4, we note that it represents many fluctuations during its evolution over time. There are peaks and troughs that appear in the same months over the years. This would reflect the existence of a seasonal component in the series. The series is therefore not stationary.

Figure 5 below shows the histogram of maximum speeds in the city of Douala. We observe a predominance of the class 6-10m / s which represents 63.33% of the dataset. Strong winds are observed very little (2.29% of the speeds are greater than 20m/s).

The maximum speed is 30m/s, minimum of 2m/s and the average speed is 9.49m/ s. The statistics associated to the series of maximum wind speeds in the city of Douala also show that the asymmetry coefficient is 1.737.

This means that the series is more spread out to the right, and thus the median moves away from the first quartile. Also, the coefficient of flattening is 7,648. We can therefore already say that this series does not follow a normal law.



	VELOCITIES
Mean	9.493750
Median	9.000000
Maximum	30.00000
Minimum	2.000000
Std. Dev.	4.052366
Skewness	1.737098
Kurtosis	7.648080
Jarque-Bera	673.4937
Probability	0.000000
Sum	4557.000
Sum Sq. Dev.	7865.981
Observations	480

Figure 5 Histogram of the monthly maximum speeds of the city of Douala from 1971 to 2010

3.3.2. Choice of the most appropriate Law

The processing of speeds will be done using the laws of the theory of extreme values. To verify if our distribution fit well with these laws, we will proceed to the graphic test using the quantile-quantile graph. The test is simple and easy to implement.

The choice of the appropriate probability law for maximum velocities will be done using the laws of the extreme value theory [21]. This law states that if $M_n = \text{"max"}\ (X_1, \dots, X_n)$ where $\{X_i\}_{(1\leq i\leq n)}$ are n independent random variables of the same distribution function G and there are two real constants sequences $A_n > 0$ and b_n such that:

$\lim_{n\to\infty} P\left\{\frac{M_n - b_n}{a_n} \leq z\right\} = G(z)$, weak convergence whithG being a non-degenerate distribution function. Then G can belong only to one of the following three laws: Weibull, Gumbel or Frechet. If we set:

$$\forall n \in \mathbb{N}, b_n = moy(M_n) = 9.493750 \text{ and } a_n = sdev(M_n) = 4.052366$$

where $moy(M_n)$ is the mean of the series of maximum wind speeds in the city of Douala and $sdev(X_n)$ its standard deviation.

3.3.2.1. Seasonal Adjustment

To seasonally adjust our series, we will simply remove the seasonal coefficients from the gross series of the twelve months, we are computing through the Excel software. This allows us to obtain the seasonally adjusted series (CVS).

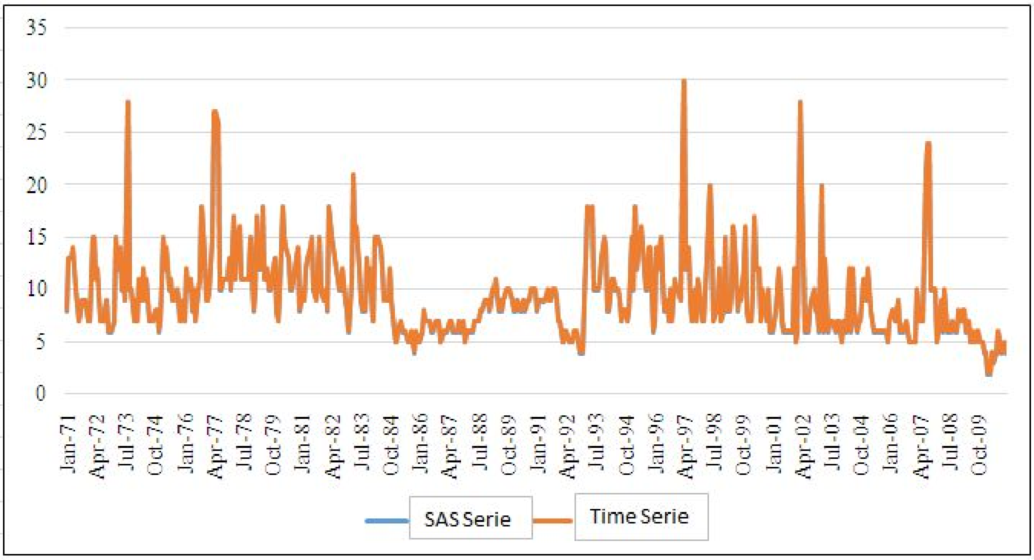


Figure 6 Representation of the time series and the seasonally adjusted series (MS Excel 2013).

We can then realize that the two series are superimposed [Fig. 6]. The series of maximum wind speeds in the city of Douala therefore has no seasons. In all the rest, the work will be carried out directly on the gross series.

3.3.2.2. Calculation of the Parameters of the Law

We are going now to assume that the maximum wind speed in the city of Douala follows one of the three laws of extreme values, we will determine its real parameters. To do this, we will use the fgev's function in the evd package of software R. We obtain the following results [20]:

```
Call: fgev(x = douala)
Deviance: 2529.596
Estimates
loc      scale      shape
7.66078  2.747558  0.08229

Standard Errors
loc     scale    shape
0.1388  0.1026  0.0299

Optimization Information
Convergence: successful
Function Evaluations: 22
Gradient Evaluations: 8
```

3.3.2.3. Test of Adequacy

To check this, we perform a new suitability test of the series of maximum wind speeds in the city of Douala to a randomly generated series which follows a Fréchet law with $\mu = 7.66078$, $\sigma = 2.74758$ and $\xi = 0.08229$ as the parameters.

The p-value of the test performed is $p = 0.1734 > 0.05$. Therefore, we cannot reject the null hypothesis of the Kolmogorov-Smirnov test. Conclusion, the series of maximum wind speeds in the city of Douala follows a Fréchet law of parameters: $\mu = 7.66078$, $\sigma = 2.74758$ and ξ=0.08229.

Figure 7 shows the curves of the distribution functions of the two series (the one of maximum wind speeds in the city of Douala and a Fréchet distribution with parameters $\mu = 7.66078, \sigma = 2.74758$ and $\xi = 0.08229$.

It can be noted that the two curves are superimposed, which confirms the conclusion of the hypothesis test performed above.

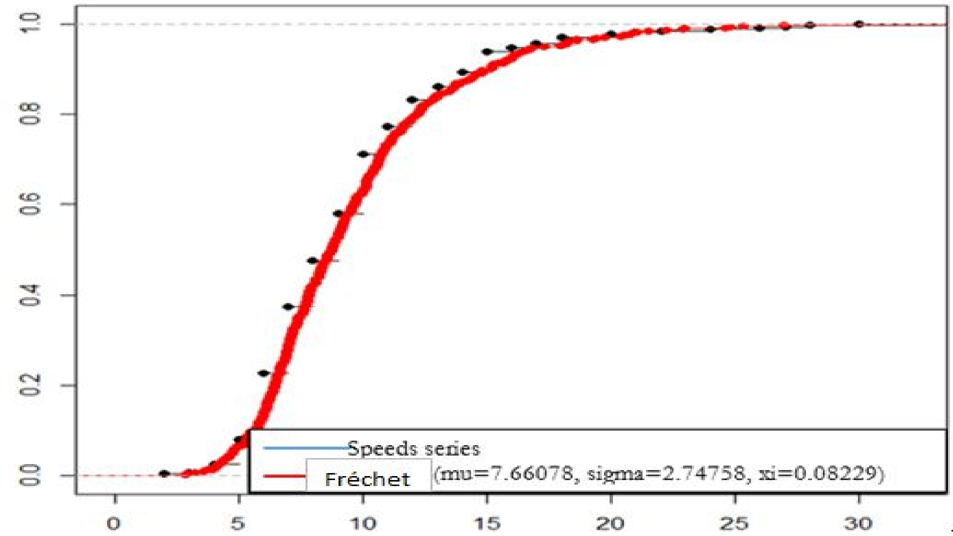


Figure 7 Distribution functions of the two series(R software)

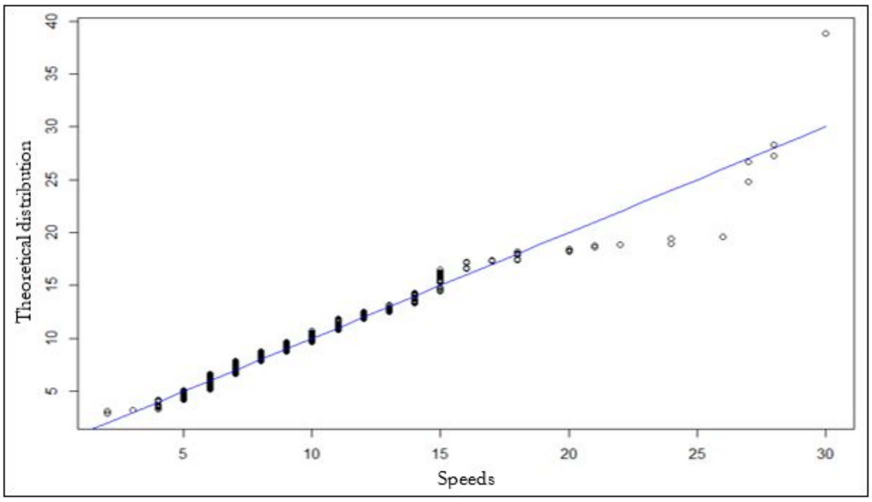


Figure 8 QQ plot (software R)

We observe that the QQ-plot are approximately linear and they fit well with the first bisector. Thus we can say that our distribution follows the generalized law of extreme values [fig. 8].

3.3.3. Quantile Estimation

The determination of the reference velocity consists in estimating the quantile for a probability of $(1 - p) = 0.98$, using the qgev function in the evd package of the R software [20].

qgev $(0.98, \text{loc} = 7.66078, \text{scale} = 2.74758, \text{shape} = 0.08229))$, we have: $q = 20.30287$.

Thus the reference speed of the wind in the city of Douala is $V_{ref} = 20.3 m/s$

4. CONCLUSION

The extreme value theory allowed us to adjust our data set, using the generalized extreme value distribution (GEV). Proceeding in this way we obtained a reference velocity of $V_{ref} = 20.3 m/s$. The estimation of this velocity would have been more correct using the daily data in the statistical treatment that we carried out. The use of monthly, or weekly data as mentioned above, causes us to lose an enormous amount of information. Unfortunately only monthly data were available. The value of V_{ref} which we have calculated corresponds more to the normal speed of the French regulation NV65. Its latest version NV65 modified 1999, departed France in 5 regions with 5 values representative of the normal speed according to Table 1. The Cameroon offices of study adopt these values by matching Table 7 below:

Table 7 Matches between regions and topographies

Topographies of the construction site	Corresponding French regions	V_{ref} (m/s)
The plains	region 1	28.6
Mountainous areas and high plateau	region 2	31.3
The Great Mountains Region	region 3	35.0
Valleys	region 4	38.3

According to the above rules, the value to be adopted for Douala is the one corresponding to region 1 (28.6m / s) significantly greater than Calculated. The difference between the adopted and the calculated value is in order of 41 %. One can then question the validity of this practice of finding correspondences between the French regions and the African regions in general and Cameroonian in particular. While it is true that France and Cameroon share the same time zone, their latitudes are very different. Moreover, France belonging to the temperate zone and Cameroon to the equatorial zone. Let us compare the value found in Douala with the values of the reference speeds of certain countries. In South Africa V_{ref} varies from 28 to 36m / s. In Algeria this range extends from 25 to 31 m / s. Belgium adopted a single reference speed of 26.2 m / s. All these values are superior to those we have obtained for the city of Douala.

This can be explained by the mechanisms of general circulation in the atmosphere. Indeed, the city of Douala and Cameroon are in the so-called equatorial calm zone which is characterized by winds of low intensity. Wind speeds are therefore overestimated in Cameroon. The impact on construction costs is not significant for low-rise buildings (most of the buildings currently built), but could be significant when constructing high-rise buildings.

5. ACKNOWLEDGEMENTS

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